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(54) Abstract Title
Collision avoidance; air traffic control

(57) An aircraft carries a GPS receiver which determines the aircraft's position in three dimensions. This is transmitted to a ground station, which determines the aircraft's trajectory and compares the aircraft's position and/or trajectory with stored data about terrain and building heights, temporary obstacles, conflicting air traffic, airways, prohibited airspace, danger areas and royal flights. Danger may be displayed visually or transmitted to the pilot by text messaging.

Alternatively the GPS receiver and the transmitter may be carried by the pilot. Transmission may use time division multiplexing (TDM) and/or frequency agility to prevent interference.

Fig.2

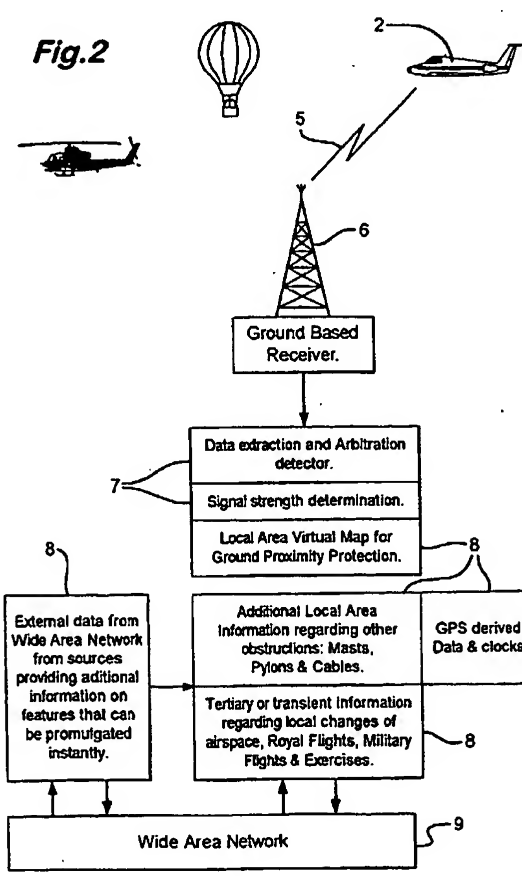

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Fig.1

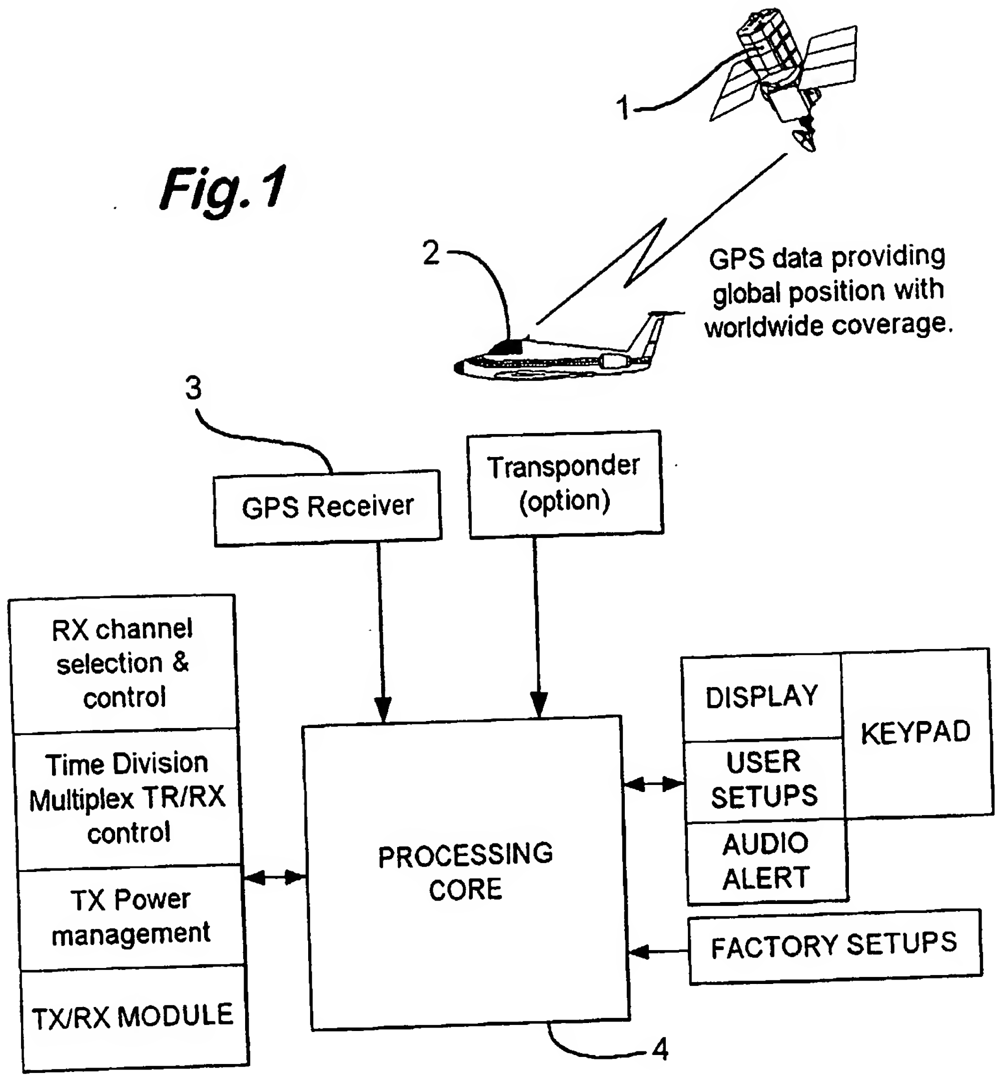
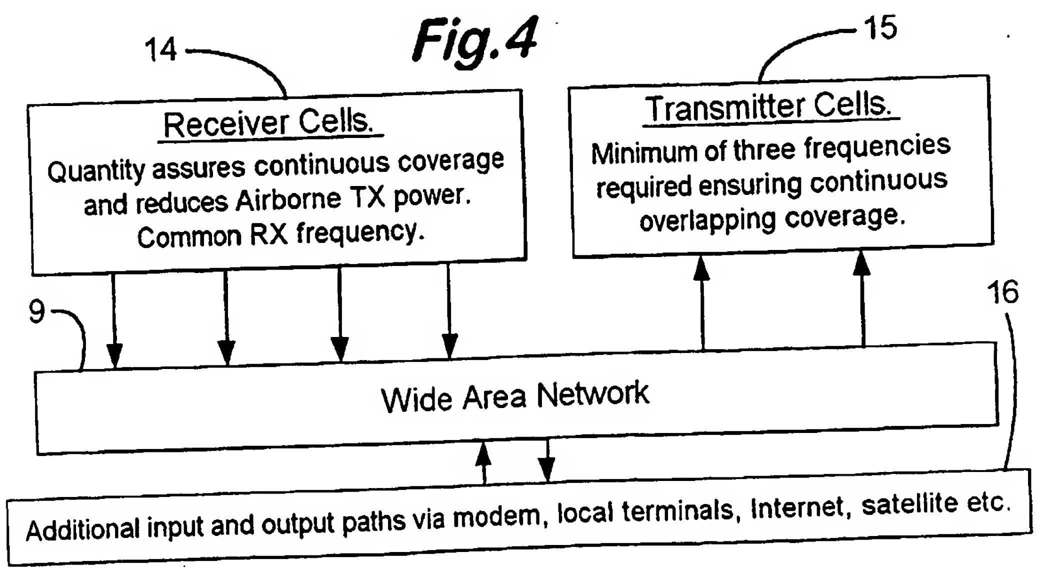
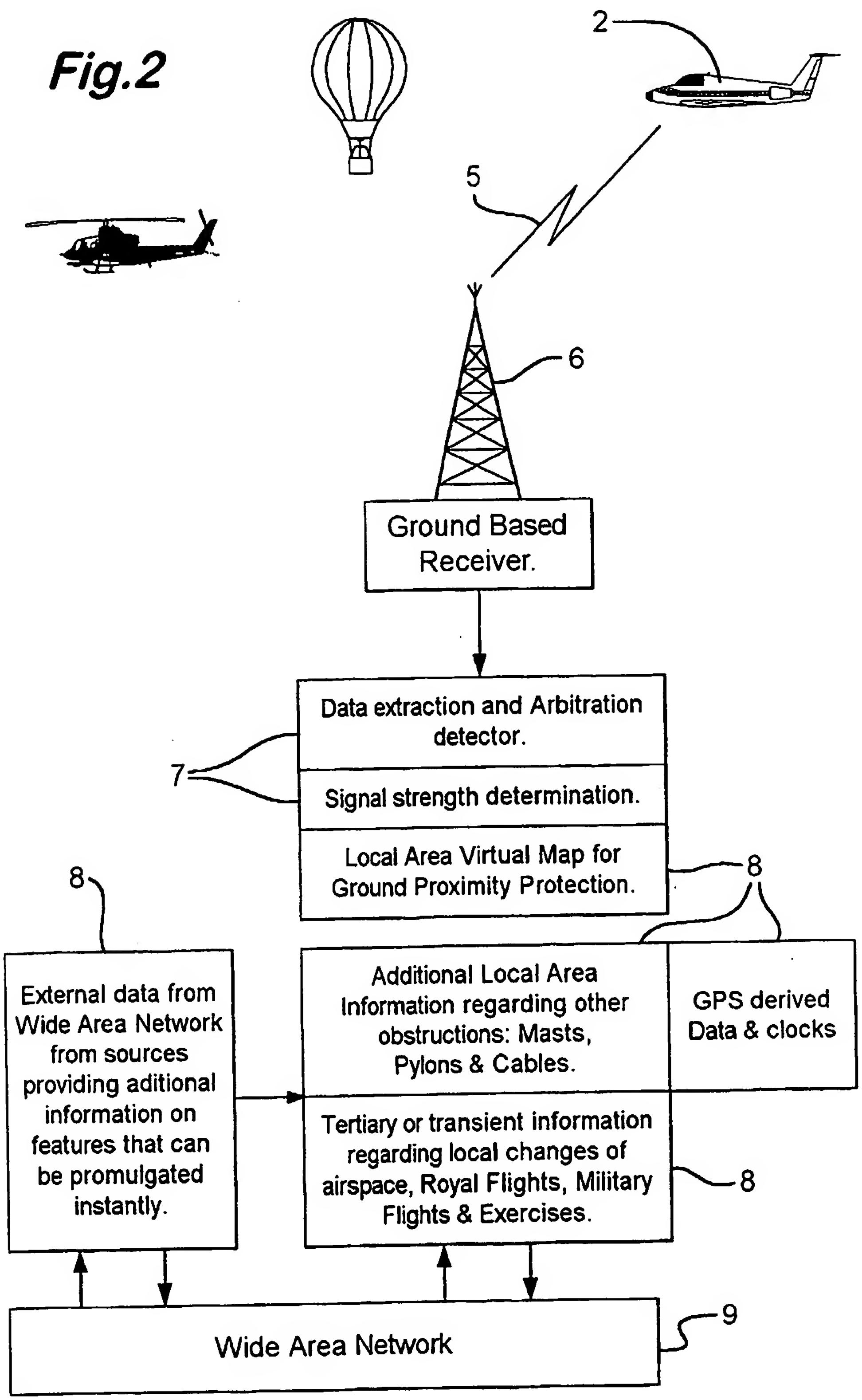

1
2
GPS data providing global position with worldwide coverage.
3
GPS Receiver
Transponder (option)
RX channel selection & control
Time Division Multiplex TR/RX control
TX Power management
TX/RX MODULE
PROCESSING CORE
DISPLAY
KEYPAD
USER SETUPS
AUDIO ALERT
FACTORY SETUPS
4

Fig.4


14
15
Receiver Cells.
Quantity assures continuous coverage and reduces Airborne TX power. Common RX frequency.
Transmitter Cells.
Minimum of three frequencies required ensuring continuous overlapping coverage.
9
16
Wide Area Network
Additional input and output paths via modem, local terminals, Internet, satellite etc.



2
5
6
Ground Based Receiver.
Data extraction and Arbitration detector.
7
Signal strength determination.
Local Area Virtual Map for Ground Proximity Protection.
8
8
External data from Wide Area Network from sources providing aditional information on features that can be promulgated instantly.
Additional Local Area Information regarding other obstructions: Masts, Pylons & Cables.
GPS derived Data & clocks
Tertiary or transient information regarding local changes of airspace, Royal Flights, Military Flights & Exercises.
8
Wide Area Network
9

Fig.2

Fig.3

10

COLLATION LAYER

- Receiver singal strength.
- Most local transmitter decision.
- Formal control packet to Ground Based TX/RX.
  Select most appropriate TX or RX for user.
- Time slice arbitration or channel conflict?
  IF clash THEN signal for arbitration.
- Collate positions of airborne objects from
  ajoining ACS cells via WAN.

11

COMMAND LAYER

- Airborne transmitter power commands.
- Airborne transmitter Time Slice Contol.
- Airborne receiver channel commands.
- Ground based tranmitter, data routing.

12

3D MAPPING LAYER

- Velocity vector extrapolation.
  1. Assess collision risk with airborne objects
  Use WAN data for 'distant incoming' craft.
  2. Assess colision risk with local terrain or
  features. (Pylons, towers, high ground,. etc)
  Local receiver, possible indications.
  3. Assess local airspace proximity.
  Local receiver and/or WAN data.

13

PROMULGATION LAYER

- Identify airborne craft.
  1. Flag 'conflict of proximity'.
  2. If 'participaating' warning or avoiding action.
  3. If 'non participating' warning only.
  4. 'AIRPROX' if less than safe passing distance.
  Preparing data packet for recipients.
  Send packets to WAN for distribution to sites.

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Anti-Collision System

The present invention relates to an anti-collision system and particularly but not exclusively for private aircraft and helicopters.

Since man has taken to the air deaths have occurred, some caused by impact with other aircraft, impact with obstructions such as towers and masts, pylons and their associated cables, high ground where forward visibility is limited and the ground itself where an incorrectly set manual system (for example an altimeter) has been maladjusted. The radar control of aircraft is a labour intensive process and requires all aircraft to participate in order to provide adequate cover. Expensive airborne systems have been designed to protect larger aircraft from undesirable sudden stops, but these systems fail where the object neither reflects a sufficient radar image nor appears on paper maps which may not show up ground features such as pylons and the like.

Air traffic control has attempted to reduce the risk of collision between heavy aircraft by channelling them down lanes of fixed dimension with fixed minimum spacing between the aircraft in time and space. However as aircraft reduce in size, their speed also reduces and the technical fit of the craft also reduces, making them unsuitable for passage in air lanes. As the population of light aircraft and their derivatives increases e.g. paragliders, hang gliders, micro-lights and many others, the risk of collision between high powered craft and craft of lesser power, increase significantly.

Most light aircraft movements occur between 1000 and 2500 feet above ground level, the air space below 1000 feet is traditionally used for the climbing and descending phases of the flight. Many flights occur at altitude to where radar coverage is poor or ineffective, typically below 500 feet. Further military training flights occur at heights between 250 and 500 feet and at velocities which make visual detection of objects likely to impede the flight difficult for the pilots of the military aircraft and almost impossible for the pilot of the

small light aircraft. To date, many expensive military aircraft have been destroyed due to impact with other air traffic.

A system which performs an anti-collision function generally suitable for air use seen as a valuable service.

WO96/02905, WO95/028650 and WO95/17685 all relate to satellite based aircraft traffic control systems incorporating ground positioning system (GPS) technology. This technology has been reported also for example in 'Flight International' 28th April to 24th May 1999 pages 46-48.

There is however a great advantage in using a ground based system into which has been input information as to the existence of ground based obstacles such as cranes, masts, air exclusion zones etc since a ground based station can be readily and swiftly updated in a secure fashion.

Accordingly therefore to the prior art there is provided an anti-collision system which comprises a ground positioning receiver operatively linked to a transmitter and adapted to output a first signal indicative of a position and a receiver module adapted to receive a first signal and process the same and output a second signal indicative of the position indicated by said first signal. The present invention provides means whereby ground based features already input into said receiver module are compared and if necessary added to said position indicated by said first signal.

In a preferred embodiment the first signal emanates from an aeroplane, a tall structure, a balloon, dirigible or unmanned craft and the first or second signal is transmitted using time division multiplexing.

It is convenient that any transmitter includes arbitration means to include frequency agility. Further the receiver module may be ground based and include means for inputting details selected from at least one of the following

a) conflicting air traffic,

b) fixed obstacle avoidance,

c) temporary obstacle avoidance,

d) airways avoidance,

e) air space avoidance,

f) royal flight avoidance,

g) danger area promulgation,

h) ground proximity warnings.

The anti-collision system of the present invention may include visual and/or voice text messaging means which may be operated to alert an operator or pilot as necessary.

The invention will now be described, by way of illustration only, with reference to the accompanying drawings:-

Figure 1 shows diagrammatically an airborne system of the invention,

Figure 2 shows diagrammatically a ground based system of the invention,

Figure 3 shows control node and

Figure 4 shows a wide area network (WAN).

Figure 1 shows an airborne system in which a satellite (1) in accordance with known technology forwards a GPS signal to an aircraft (2). Aircraft comprises a GPS receiver (3) which extracts a position, altitude, heading and velocity information via a processing core (4). The processing core then calculates *inter alia* the altitude and ground speed of the aircraft (2).

The processing core (4) therefore provides a data packet containing a compressed position, an ID, user setups, optionally a transponder code and passes it to the transmitter module (TX module) for transmission during a selected time slice. The receiver module (RX module) provides the core (4) with data from ground transmitter including arbitration commands, power management and time slice commands. This may be verified by a return of the ID or call sign and a CRC or checksum for a data integrity check.

The processing core (4) extracts relevant data from this transmission and may provide a text message which can specify a threat or pass a request etc. Additionally the aircraft (2) is provided with a GPS aerial where one is not already available and a belly mounted aerial to communicate with ground base WAN systems.

Figure 2 relates to a ground base system receiver and transmitter. Thus the aircraft (2) outputs a second signal (5) from processing core (4) to the ground based receiver (6). The ground based system comprises a geographically strategic receiver to gather airborne flight data. From this data is extracted a signal strength determination (7) in accordance with the prior art practices. A local area virtual map of ground proximity protection, additional local area information regarding other obstructions such as masts, pylons, cables etc tertiary or transient information regarding local changes of air space, royal flights, military training flights and exercises are added to external data from the wide area network. Sources providing additional information on features that can be promulgated instantly (8) and compared with information from the signal (5). The wide area network (WAN) will provide a portion of this information.

The ground based receiver (6) also comprises a control node shown diagrammatically in Figure 3. This control node comprises a collation layer (10), a command layer (11), a 3D mapping layer (12) and a promulgation layer (13). Turning first to the collation layer, the ground based system (6) measures the receiver signal strength to allocate the most suitable local transmitter and subsequently that transmitter selects the most appropriate transmitter/receiver for use. If there is a time slice arbitration or channel conflict then arbitration is initiated at the same time as indicating the position of airborne objects from adjoining ACS cells via WAN.

The command layer (11) comprises an airborne transmitter power command. It also comprises an airborne transmitter time slice control, airborne receiver channel commands and a ground based transmitter for a data routeing function.

The 3D mapping layer (12) comprises means for velocity vector extrapolation which tests collision risk with airborne objects using data for distant incoming aircraft, assessing the collision risk with local terrain and/or features such as pylons, towers, high ground etc. while assessing local air space proximity via local receiver and/or WAN data.

The promulgation layer (13) identifies airborne aircraft, proximity conflicts, plus if 'participating' warning or avoiding action is started, whereas if 'non-participating' only a warning is promulgated. Airprox is indicated if less than a safe passing distance is apparent, while preparing data packets for recipients and sending packets to WAN for distribution to relevant sites.

With reference to Figure 4 the communications infrastructure is readily available, to disseminate data gathered from receivers to the processing section which can be geographically sited and which will pass collision or risk data to the relevant transmitter station that is geographically closest to the aircraft which may be communicating with different receivers due to local geography. A wide area network (9) WAN may comprise receiver cells (14) and transmitter cells (15). The receiver cells (14) assure continuous coverage while reducing as far as is possible airborne transmitting power to a common receiver frequency. The transmitter cells (15) comprise a minimum of three frequencies which are required to ensure continuous overlapping coverage. The wide area network (9) may be updated merely by additional inputs and outputs via local modem, internet, or satellite etc (16). The aforegoing gives the elements of a process in accordance of the present invention but the method of construction is set out hereunder.

The airborne system (Figure 1) employs Time Division Multiplexing techniques to increase the number of simultaneous users, and a single transmitting frequency to reduce the need for agility in the airborne system.

The mobile fixed frequency transmitter communicates with one or more ground based receivers (Figure 2).

Data from the aircraft is passed using the WAN (Figure 4) to a processing system or control node (Figure 3) which:

- Assesses received signal strength
- Allocates a receiver and a ground based uplink transmitter.
- Modulates the airborne transmitter power to minimise the radiated footprint and increase the overall receiver network sensitivity.

Data relevant to the particular aircraft is compared with data from geographically close aircraft in order to assess collision risk, taking into account the relative velocities and headings in all dimensions.

The software can dynamically adjust the equivalent of 'space' required by analysing the flight profile.

Aircraft that change height and heading are given a larger 'space' than aircraft which have shown a continuous flight path which would therefore have their 'space' extending in the direction of flight proportional to their velocity.

Risk assessment is augmented by incorporating local area features and terrain into the virtual map contained within each processing system, updated as required for special cases such as tower cranes, Royal Flights, and military training.

Towers, pylons and their cables can be added to provide a 3D 'keep out' zone which can include a 250 foot (say) ground proximity level.

The proposed system uses a 5 second timebase, derived from GPS clock information, split up into 50 'channels' or time slices of 100mS each, again accurately controlled from the GPS clock.

The determination of the 5 second timebase is as follows.

Two craft on a direct head to head course at a closing speed of 240 mph will close on each other at 352 feet per second. (120 mph is not an uncommon speed for an average, single engined light aircraft.)

In 5 seconds the two craft will have closed by another 1760 feet, or a third of a mile. A detection area of 5 miles around a craft could therefore warn of a collision some 25 seconds before the event.

With an occupancy of 50 aircraft, and a maximum warning range of 5 miles, the probability of a 5 mile sphere having a flying population of 50 aircraft, which relates to one aircraft for every 500 foot of vertical separation distance from the ground up to 25,000 feet is statistically low. (25,000 feet is approximately 5 miles)

The GPS data comprising position, altitude, calculated ground speed and heading is transmitted in one of 50 time slices to the ground based receiver (6).

Additional data comprising the aircraft identity, callsign and other information is added. The entire data packet is defined in an Aircraft Transmit Protocal. (ATP)

The maximum radiated power required from the aircraft transmitter is determined by the received signal strength at the ground based receiver, (much like current GSM mobile telephones).

A Wide Area Network (WAN), or communication infrastructure sends anti-collision system (ACS) data to a distant master transmitter Figure 4 or control node Figure 3. Participating aircraft will use one of 50 time slices or channels of 100mS in which to send their positional and other relevant data to ground based receivers, (Figure 2).

Return data from the ground can be transmitted using similar packet techniques, offset in time to allow for TDM (Time Division Multiplexing) using a common aerial.

When two aircraft begin the service on an identical time channel and both are picked up by one ground based receiver, the system may flag, using the uplink time slice that relates to this particular receiver channel, that reception was unsatisfactory.

The closest ground based transmitter would indicate that arbitration is required by flagging that particular channel as currently being used by two (or more) aircraft.

An adaption of the system could allow verification that the channel about to be used is clear by examination of the relative time slice from the ground. The probability that two or more craft may target the same channel is low but arbitration may still be required. This is defined in the ground station transmit protocol.

Channel changing is brought about by employing the aircraft registration, where applicable, as a pseudo random seed to reduce the probability of the same aircraft re-entering the system on the same channels for a second time.

Alternatively, the control node can instruct a specific channel change, especially if the craft is to be handed on to another ground based transmitter, which must operate on a different frequency to that already in use.

To prevent a channel change coinciding with a channel already in service, the arbitrating aircraft, if 'landing' on an occupied channel, would reapply the pseudo random seed to recalculate another channel.

Channel occupancy can be determined by referring to the received data from the ground based transmitter, knowing the relationship between a time slice channel from air to ground and a time slice channel from ground to air.

The ground station transmit protocol also includes commands to increase or reduce the aircraft transmitter output power.

The number of ground based receivers is reduced by virtue of the altitude of the aircraft which will have an almost line of sight communication range with more than one receiver. Additionally, the number of ground based master transmitter stations is reduced likewise. The consumption of air and ground radio spectrum can be as low as one single 'unicom' channel.

The control of air to ground transmit power is controlled by the primary ground receiver. Any receiver that subsequently takes command of a craft becomes the new primary ground receiver.

Ground receiver arbitration as to which base station is in control of a particular aircraft transmit power is achieved over the WAN. Such techniques are in use for mobile phone control and channel changing.

Ground to air spectrum usage can be as little as three radio channels which is the theoretic number required to populate a cell structure of regular six sided polygons. The necessary radio spectrum can be derived from use of co-operative systems such as digital radio, or data transmission techniques like RDS. The maximum continuous data rate to handle the proposed system such as digital radio is 4800 baud. Additional features that may be derived by adoption of the service:-

- Fixed obstacle avoidance
- Airways avoidance
- Royal flight avoidance
- Danger area promulgation
- Ground proximity warnings

For use of the ATP, a five second time base is derived from the GPS master clocks available from the GPS module and is divided into 50 channels of 100mS each.

Within the 100mS channel, a data packet is transmitted which contains the following

HEADER	1 byte signifying the start of data.
DEFINITION	1 byte comprising data defining the service this user is participating in.
AIRCRAFT	1 byte coded to reflect the type of aircraft participating.
CALLSIGN	6 bytes, compressed data encoding up to 8 alpha numerical characters.
POSITION	4 bytes, compressed data encoding GPS derived longitude and latitude.
ALTITUDE	1 byte giving altitude in 100 foot units (max = 25,500 feet).
SPEED	1 byte giving ground speed from 0 – 255 knots.
HEADING	1 byte encoding 360 degrees into 1.4 degree segments (approximation).
FROM/TO	5 bytes compressed data encoding ICAO destinations i.e. EGSS= Stanstead.

T/PONDER 2 bytes compressed data encoding 4 digit transponder code.

CHECKSUM 1 or 2 bytes to check validity of received data at the receiver.

This comes to 25 bytes of 8 bits each.

Employing a simple AFSK or FSK serial protocol to modulate the transmitter, and using standard serial data protocols already in common usage requires 11 bits of data. E.g. 8 data bits, 1 start bit, 1 stop bit, 1 parity bit. 8 + 1 + 1 + 1 – 11 bits.

25 bytes of 11 bits = 275 bits per packet.

From the 100mS time slice, allow 10mS head room for transmitter on and off times allowing 90mS in which to send 275 bits.

This equates to 275/0.9 = 3050 bits per second, which allows for low cost and low technology use of 4800 baud data rate from air to ground.

Employing a defined rise and fall time for transmit power reduces spurious radiation and artifacts reducing or eliminating interference with airborne systems.

Any advance, available cheaply by simple extraction of design stages from current communications technology, can serve to increase the data rate and thus increase the number of aircraft that can be serviced.

Changes to data composition can be made as necessary. The alpha numeric figures used here have been constructed to derive a working data rate within current data rate transmission specifications and limitations.

Aircraft Transmit Protocol in detail. (ATP Downlink)

HEADER 1 byte signifying the start of data.

This byte contains fixed data signifying the start of a data block.

DEFINITION 1 byte comprising data defining the service this user is participating in.

1 bit = Participation or Non Participation

PARTICIPATION implies that this user can take avoiding action and that the system is capable of displaying the necessary text to the pilot.

It also states that the user can acknowledge receipt of avoiding action by operation of a panel mounted button in order to signal to the ground station that the collision risk has been received.

NON PARTICIPATION implies that the user cannot affect their craft sufficiently for any avoiding action to be either swift or effective.

Any participating or non participating user should be able to acknowledge the warning.

The ground based station can then upgrade the warning to the converging participant informing the user of what avoiding action to take.

An example of a non participating service could be a balloon, which is moving in the surrounding body of air and which may not have sufficient power in it's burners, if available, to effect a satisfactory change of altitude.

It is unlikely that two or more non participating users would find themselves in a risk of collision.

The only example would be a balloon rising into the basket of another balloon where the lower balloon cannot see the higher due to the masking effect of the envelope.

1 bit = Warning acknowledged

This is received by the ground station and used to log the Airprox.

1 bit = SMS capable. See Ground Based Transmitter Protocol.

1 bit = Radio/non Radio.

1 bit = VFR/TFR flight rules.

1 bit = Transponder equipped. (availability of separate transponder)

1 bit = 'Mode C' (ability of the transponder to add altitude data)

AIRCRAFT 1 byte coded to reflect the type of aircraft participating.

1 bits Aircraft types classed as:-

Fixed wing.

Rotary wing.

Microlight.

Glider or sailplane.

Balloon. Including airship which could 'participate'

Royal Flight Which would 'Non Participate'

Danger area * special case of non-participation

Obstacle * special case of non-participation

1 bit FORMATION

This could indicate one of a number of aircraft where visual separation is maintained as part of the flight specification and where it is not necessary to occupy additional spectrum.

Red Arrows on display.

Battle of Britain memorial Flight.

Royal Flight.

Tiger Moth appreciation flight.

4 bits Special/Military

These can instruct the ground station to effect a certain airspace restriction based on the code employed in the bits.

CALLSIGN 6 bytes, compressed data encoding up to 8 alpha numerical characters.

Compression formula.

To allow characters 0 – 9 requires	10 characters
To allow alphabetical characters requires	26 characters
To allow a space and '-' symbols requires	2 characters
Total characters required for any callsign	38 characters

38 characters can be defined in only 6 bits, giving a maximum definition of 64 characters including the use of '000000' as a valid character.

8 characters of 6 bits require 48 bits, which can be realised in 6 bytes and 8 bits.

POSITION 4 bytes, compressed data encoding GPS derived longitude and latitude.

Compression formula.

A position on the earth takes the form of 52° 24" 16'N

02° 12" 22'E

As this data is being received on the ground by a base station in geographically close proximity to the participating aircraft so some scope for data reduction is possible.

1 degree of arc represents approximately 60 nautical miles on the earth's surface.

As the maximum range of the aircraft transmitter is 10 miles, a position received without the most significant degrees information and limited to the minutes and seconds will provide a position to within 100 feet unambiguously, as the only other position in a northerly or southerly direction which would share the least significant part of the position is 60 nautical miles away.

The 'N' and 'W' components can also be discarded.

This leaves 8 data bytes. In this case 24, 16, 12 and 22.

These bytes can be compressed into 4 bytes as only 4 bits can represent 0 – 9.

ALTITUDE 1 byte giving altitude in 100 foot units. (max = 25,500 feet)

For metric application, apply 30 metre units giving 7650 metres or 24,862 feet.

SPEED 1 byte giving ground speed from 0 to 255 knots.

The inclusion of planes exceeding 512 knots could be achieved by using a multiplier of 2. This could be in the form of a multiplier bit with the actual multiplier, 2, 3 etc included in a control byte from the aircraft.

HEADING 1 byte encoded 360 degrees into 1.4 degree segments. Encoding 360 degrees into 256 'pseudo degrees of 1.4 'real' degrees reduces the data requirement from 2 bytes to one.

Any extended track inaccuracies are extremely small over the 5 second, system refresh time.

FROM/TO 5 bytes compressed data encoding ICAO destinations i.e. EGSS = Stanstead.

Compression formula

8 alphabetical characters, 1 of 26, only require 5 bits to represent any character.

6 characters require 40 bits, which can be expressed in 5 bytes of 8 bits.

T/PONDER 2 bytes compressed data encoding 4 digit transponder code.

Compression formula

A 4 digit transponder code i.e. 7600 (radio failure) requires only 4 bits to represent any digit from 0 to 9. Four digits of 4 bits require 16 bits, which can be expressed in two bytes of 8 bits.

Preset to 1234 Conspicuity code.

CHECKSUM 1 or 2 bytes to check validity of received data at the receiver.

Absolute validity of the received data is essential.

For this reason, up to 2 bytes is put aside for either a checksum or cyclic redundancy check (CRC).

Any further additions of data or CRC bytes remain within the specification of 4800 baud.

The ground based receiver may be co-sited with a current GSM mobile phone installation. This provides the mast and a local power supply. The ground based receiver may however be a 'stand alone' system located as required for specific needs.

Access is required to a WAN (Wide Area Network) which is used to send aircraft data as received, plus any other data handling algorithms required by the native WAN, to arrive at the closest geographical base station that is the ACS controller and information transmitter. Any receivers (Figure 2) able to receive the same user will arbitrate between themselves to determine which of these is receiving the strongest signal.

Data is prepared by the Control Node (Figure 3) to be radiated by the transmitter to the participating aircraft to reduce or increase the radiated power. This feedback reduces any interference on the plane, minimising unnecessary data shuffling around the WAN.

Failure to achieve satisfactory transmitter control within the aircraft will reduce the service capability of the local area surrounding the plane as it is intended that a single transmit frequency can be used by the entire system in order to reduce the complexity of the overall system by eliminating the need to engineer a frequency agile transmitter within the aircraft with the attendant technical complexities and increased 'lock up and acquisition' times.

In the simplest form, the ACS control node is a PC based system capable of taking data from the WAN and extracting the position, altitude, heading, callsign and speed information of each aircraft requiring a 'Participation' or Non Participation' service.

The ACS System comprises a number of Control Nodes.

There will be sufficient ACS Control Nodes geographically located to provide a country wide ACS service with the minimum of additional infrastructure.

The ACS Control Node PC will run dedicated software designed to take data from the ground based receiver (possibly via the WAN) as well as input from external sources, plus the ability to filter data for selective transmission over the WAN, to any destination in the country.

The program will calculate velocity in either level flight or climbing or descending phases. Information about the aircraft velocities are used in order to assess the probability of a risk of collision within a time frame of 25 seconds.

The ground based transmit protocol then informs both aircraft of the risk.

The ground based receiver and the ACS Control Node can receive additional input from external sources, as well as operate on data available regarding the local area surrounding the aircraft.

Additional input can take the form of;-

- Variable inputs.

  These can be Danger Area Promulgation where the area can be activated and deactivated by an activity on the site itself.

  e.g. A Gas Venting Station for instance may activate a local danger area up to, and during some venting operation where the effects of rising gas or heat may cause a risk to light aircraft.

- Fixed inputs

  These can be towers or masts, which should be avoided.

  Pylons and power cables.

  Employing simple, 3D modelling, the controlling computer can erect a solid plane around the pylon and the cables. Pylons closer than a determined distance can be regarded as joined by cables, even if not.

  Surface features.

  As above, hills and mountain data can be input and a safe layer built around them.

  Where the area is effectively flat, a 250 foot ground proximity layer can be created reducing controlled flight into terrain.

For an effective Anti-collision System to operate to the advantage of all aircraft, be they ACS equipped or not, full integration into the nationwide radar networks can be implemented.

Integration allows data from a specific ACS control node to be sent to the radar centre at Daventry, providing that service with additional data from ACS equipped aircraft to be added to the radar returns, reducing the number of unidentified echoes as these are identified from the ACS data.

Integration allows data from a radar installation to supplement ACS inputs with information regarding locally controlled aircraft that may not have ACS fitted.

Consider a military airbase, which may, in peacetime, and during exercises supplement their 'keep out' status with additional information as to the presence of fast moving planes which could represent a threat to light aircraft.

Military installations could either participate in the service by communicating with the local ACS control node by telephone line, modem etc, or could employ their own local ACS transmitter based on the airfield, or in the training area.

This military unit may employ the additional bits in the aircraft transmitter protocol to inform the ACS control node of the 'keep away' requirement without unnecessary radio communication with local traffic, which will be ACS equipped.

The relative velocities make it hard for either pilot to see the other in time for avoiding action to be taken, and fatalities resulting are usually civilian.

Whilst the ACS system has a necessarily limited range for light aircraft, a military input to the ACS control node would extend the military flight line, or define an area in which the military traffic is operating, thus a variable danger area can be promulgated as required.

The presence of light aircraft traffic is fed back to the military by the ACS control node which will flag that:

- The danger area contains one or more light aircraft.
- Provide the necessary information to the military that can then be made aware that the danger area is not yet clear.

The target light aircraft in the newly defined danger area will be warned by the ACS system with an appropriate message "Military exercise area" and by SMS (Small Message Service) "Entering MATZ. Contact Wattisham 132.45".

Additional safety in flight would result from reduced radio traffic as aircraft type, destination, flight rules, position and altitude would be available automatically. Radio communication would not require passage of data already presented by the ACS.

Less radio traffic would increase flight safety due to the reduction of traffic that could be misunderstood.

The ground based system which includes the entire network of control nodes could receive 'requests for information' from a local airfield, which may be operating from a small grass strip.

It is appreciated that military participation may not extend to exercises where aircraft capabilities in terms of top speed, rate of climb etc can be derived from ACS interrogation, and thus breach national security.

Data from the ACS control node provides the necessary information on ACS equipped aircraft and supplementary information from WAN connected radar services, to the airfield which, running a smaller version of the PC based program employed by the ACS control node, will provide a local area '3D radar display' for that airfield.

Small 'AG' air/ground 'discretionary' airfields could alternately operate a ACS receiver connected to a PC running software to display, in 3D if necessary, all ACS only aircraft in the area.

ACS data can be input to the local ACS control node as part of a geographical map showing masts, towers, pylons and power lines and high ground.

IFR pilots in IMC conditions rely on manually set instruments to indicate altitude above ground, or sea level.

Incidents where an incorrectly set altimeter or incursions below the designated decision height have resulted in fatalities.

Additional fatalities have occurred where pilots have become uncertain of their absolute position, although they are most certainly not 'lost'.

This situation results in what is called "controlled flight into terrain".

An ACS control node would be aware of an aircraft's position and altitude using the GPS data from that aircraft.

Any proximity to an object in the foreseeable flight path will be relayed to the pilot who will be given more of a chance to take corrective action.

Cranes and other temporary high structures can also be input to the system.

In the case of fixed obstacles and high ground. Data will be fixed and built into the ACS system map as part of the cells "local area knowledge base".

Temporary structures such as tower cranes can easily be equipped with a ACS "aircraft" transmitter with data being coded to represent a non participating service, a "callsign" which can follow an agreed format to indicate a temperature structure with additional data to include the height of the obstacle and the necessary 'keep out' zone.

The callsign format of 8 characters allows for worldwide and internationally agreed obstacle callsign codes over and above the complete range of callsigns with their national prefixes.

The ground based transmit protocol informs both aircraft of a risk using one or more of the following methods.

1) Display a pre-programmed text message based on the most likely collision directions.

"Nothing known to conflict"

"Look Out" +	"Ahead"	
	"Right"	
	"Left"	
	"Behind"	(physically difficult but a valid condition)
	"Below"	
	"Above"	
target risk, i.e.	"Fixed wing"	
	"Rotary wing"	
	"Microlight"	
	"Balloon"	(including Airship)
	"Royal flight"	
	"Flight information"	
Additional risks	"Danger area"	
	"Obstacle"	(tower, mast etc)
	"High ground"	
	Ground proximity"	
	"Airways"	(also controlled airspace)
	"Military exercise area"	
	"Local weather"	(fog, snow etc)

2) Display a message conveyed using SMS.

A service bit is available in the aircraft transmit protocol to inform the ACS controller that the user is SMS equipped.

Such a message could read "Contact Wattisham 132.45"

The user would acknowledge receipt using the same acknowledge bit in the aircraft transmit protocol as would be used to acknowledge a collision warning.

Additional data is transmitted to the aircraft to modulate the aircraft transmitter power, to reduce the radio footprint.

Additional data is transmitted to the aircraft to inform the on board ACS receiver to switch to another frequency as it becomes necessary or as the aircraft navigates closer to a cell which has greater signal strength.

This data would also include an indication of which data time slice is available at the next ACS cell. This feature would reduce the probability of a channel arbitration cycle and the few seconds of loss of protection whilst arbitration takes place.

HEADER 1 byte signifying the start of data.

This byte contains fixed data signifying that start of a data block.

DEFINITION 1 byte comprising data defining the data that is to follow.

4 bits = Message number. (Preset messages to be displayed)

1 bit = SMS data available (If system is equipped to read SMS)

CALLSIGN 6 bytes, compressed data encoding up to 8 alpha numerical characters.

Compression formula.

To allow characters 0 to 9 requires	10 characters
To allow alphabetical characters requires	26 characters
To allow a space and '-' symbol requires	2 characters
Total characters required for any callsign	38 characters

38 characters can be defined in only 6 bits, giving a maximum definition of 64 characters including the use of '000000' as a valid character.

8 characters of 6 bits require 48 bits, which can be realised in 6 bytes of 8 bits.

The callsign is used to confirm that the data is for this user.

COMMAND 2 bytes comprising data defining system instructions

1 byte of channel data

2 bits comprising coded instruction to	00	do nothing
	01	change time slice
	10	change receive channel
	11	change time slice and receive channels

6 bits comprising a time slice number from 1 to 50

6 bits can represent a number up to 64 (including 0)

values above 50 can take special meaning:

51 means	"No service, maintain your own lookout"
52 means	"Service will terminate shortly"
53 means	increase TX power,

etc.

Additional values to mean other things as required, to a maximum of 64.

1 byte of receiver channel data

4 bits encoding receiver frequency used to receive data from a ground based LAACS controller. Expandable to 16 channels in this case.

4 bits unidentified.

EXTENDED 18 bytes for either a local text message for the user, where SMS may not be available, or future expansion of the ACS system.

CHECKSUM 1 or 2 bytes to check validity of received data at the receiver.

Absolute validity of the received data is essential.

For this reason up to 2 bytes is put aside for either a checksum or cyclic redundancy check.

Any additional data or CRC bytes will not exceed the specification of 4800 baud. This ground based transmit protocol comes to 25 bytes of 8 bits each.

Employing a simple AFSK or FSK serial protocol to modulate the transmitter, and using standard serial data protocols already in common usage requires 11 bits of data being ....

8 data bits, 1 start bit, 1 stop bit, 1 parity bit. 8 + 1 + 1 + 1 = 11 bits.

25 bytes of 11 bits = 275 bits per packet.

The data rate for the uplink and downlink paths are identical allowing low cost 4800 baud data rates.

The ground based transmitter is radiating continually hence there is no requirement to allow for transmitter on and off times, thus easing the requirement of the aircraft decoder design.

The actual data rate approaches 3000 baud which still allows for low cost and low technology use of 4800 baud data rate from ground to air.

The uplink data relating to a specific time slice channel, used to receive data from the aircraft, can be transmitted some time after the data is received.

This allows the TX/RX time division multiplexing technique to ensure that it will not be transmitting during a time when data should be received from the ground.

Allowance is made for the receiver to switch from completely muted in transmit mode, to fully sensitive within very few mS.

Any delays caused by the WAN will cause the relevant data to be held until the correct time slice is available for the uplink.

In the case of a 5 second timebase as suggested here, responding to a particular aircraft after 4 seconds allows for many times more than the expected processing delay over a WAN as can be experienced over a GSM telephone conversation for instance.

Any advance, available cheaply by simple extraction of design stages from current technology, can serve to increase the data rate and thus increase the number of aircraft that can be serviced.

The ACS system as described could employ current GSM fixed point services to provide geographic locations for discrete ACS receivers and ACS transmitters.

Communications infrastructures already exist and operate well with a considerably higher volume of data traffic than is likely with the introduction of relatively few and relatively slow data rates from and to the ACS system. (Averaging 4800 baud duplex).

Any wide area network could easily handle additional 4800 baud data rates, modulated to slot into current data transfer protocols.

Point of presence is available from most Internet Service Providers, and many organisations have internal WAN systems in place.

The national radar service is one such network.

Input to and data from the ACS system can be disseminated to fixed locations using current infrastructure.

Airborne data from aircraft is available from GPS receiver modules providing NMEA data, which encodes time, position and altitude.

The processing to determine velocity and heading is available in GPS receiver units which have been so designed to extrapolate this information for the user.

Additional data that the user of an airborne ACS system can input will be by keypad and LCD, both of which appear on most GPS navigation systems.

This data would be the aircraft's callsign, ICAO information in the form of from and to data. Transponder codes which can be input by the user if required, or extracted from the aircraft's transponder unit.

Transponders can take external data from a separate pressure module to provide altitude data within the transponder data format. This is defined as "Mode Charlie" in aviation circles.

The ACS system can supplement non-mode charlie transponders with altitude information gleaned from GPS data which is historically more accurate than pressure sensing transponder units.

Data available to regional air traffic control centres can be sent to an ACS control node to supplement the ACS system with information and traffic from sources that may not be ACS equipped, but are under radar coverage or control.

Military traffic control systems can add ACS data to their own radar display systems reduce the airprox hazards between military and civilian flights.

The ACS system has been designed with the weight of complexity and computational power located on the ground.

The aircraft system can be manufactured within a unit as small as a mobile phone. Such a small unit need not be installed within the aircraft on a permanent basis reducing the cost of installation to the user.

The airborne ACS system comprises a GPS receiver module and the necessary computational power, as already exists in such units, to perform the extrapolation of velocity and heading.

The transmitter module can employ data transmission methods as already used in digital telephones with data interfaces.

The GPS aerial, which may already be present on some aircraft, can be either added to, or connected directly, field strength losses permitting.

This aerial is generally above the aircraft for a clear view of the sky.

The downlink transmitter aerial, which is only powered for 100mS every 5 seconds, in this case, provides minimal system disturbance to any other belly mounted aerial systems.

Provision for a 5mS rise and fall time for the transmitter will reduce radiated spurious emissions considerably.

The belly mounted aerial is an omni directional device, downward facing with a sideways profile that restricts the 'view' of the horizon as ground based receivers are stationed at relatively high angle i.e. predominantly downwards but not necessarily on the horizon.

The interface used to connect the receiver and the transmitter is handling slow speed digital data at a maximum data rate of 4800 baud in real time.

CLAIMS

1. An anti-collision system comprising a ground position receiver operatively connected to a transmitter and adapted to output a first signal indicative of position, a receiver module adapted to receive said first signal and process the same and output a second signal indicative of position indicated by said first signal, characterised by the provision of means whereby ground based features input into said means are compared with and if necessary added to said position indicated by said first signal.

2. An anti-collision system according to claim 1 positioned in an aeroplane, ship or un-manned craft.

3. An anti-collision system according to claim 1 carried by person piloting a machine such as a microlight, hang-glider, balloon or dirigible.

4. An anti-collision system according to any preceding claim wherein said first signal is transmitted using Time Division Multiplexing.

5. An anti-collision system according to any preceding claim wherein the transmitter module includes arbitration means including frequency agility.

6. An anti-collision system according to any preceding claim wherein the first signal output from said ground based transmitter to said aircraft is selected from at least one of the following:-

   a) conflicting air traffic,
   b) fixed obstacle avoidance,
   c) temporary obstacle avoidance,
   d) airways avoidance,
   e) airspace avoidance,
   f) royal flight avoidance,
   g) danger area promulgation,

h) ground proximity warnings.

7. An anti-collision system according to any preceding claim including a visual display or voice text messaging means.

8. An anti-collision system according to any preceding claim including means indicative of likely trajectory.

9. An anti-collision system according to claim 1 and substantially as hereinbefore set-forth with a reference to, and/or as illustrated in, any one of the accompanying drawings.

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Application No: GB 0106785.9
Claims searched:

Examiner: Dr E.P. Plummer
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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.7): G01S 5/00, 5/14; G08G 5/04; B64D 45/00, 04

Other: Online: Internet, WPI, PAJ, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2348333A	IFCO whole document	1,3,6,7
X	GB2321889A	LEVINE whole document	1,2,4,6,7,8
X	GB1136359	CHISHOLM whole document	1 at least
X	WO85/01794A1	NAVIGATION SCIENCES whole document	1,2,4,6,7
X	US5548515	PILLEY ET AL whole document	1,2,4,6,7
X	US5515286	SIMON whole document	1,2,4,6,7,8
X	US4835537	MANION whole document	1,2,4,6,7,8
X	DE10005175A	GERDTS whole document	1,2,4,6,7,8

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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